A framework for assessing adaptation strategies for plants threatened by climate, land use, and altered fire regimes

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Climate Change and Species Vulnerability

- Shift, fragment, reduce, increase available habitat
- Plants in Mediterranean-type ecosystems
- May disproportionately affect different species
  - Poorly dispersing or rare
- Impacts compounded with other threats
  - Land use change, altered fire regimes, exotic species

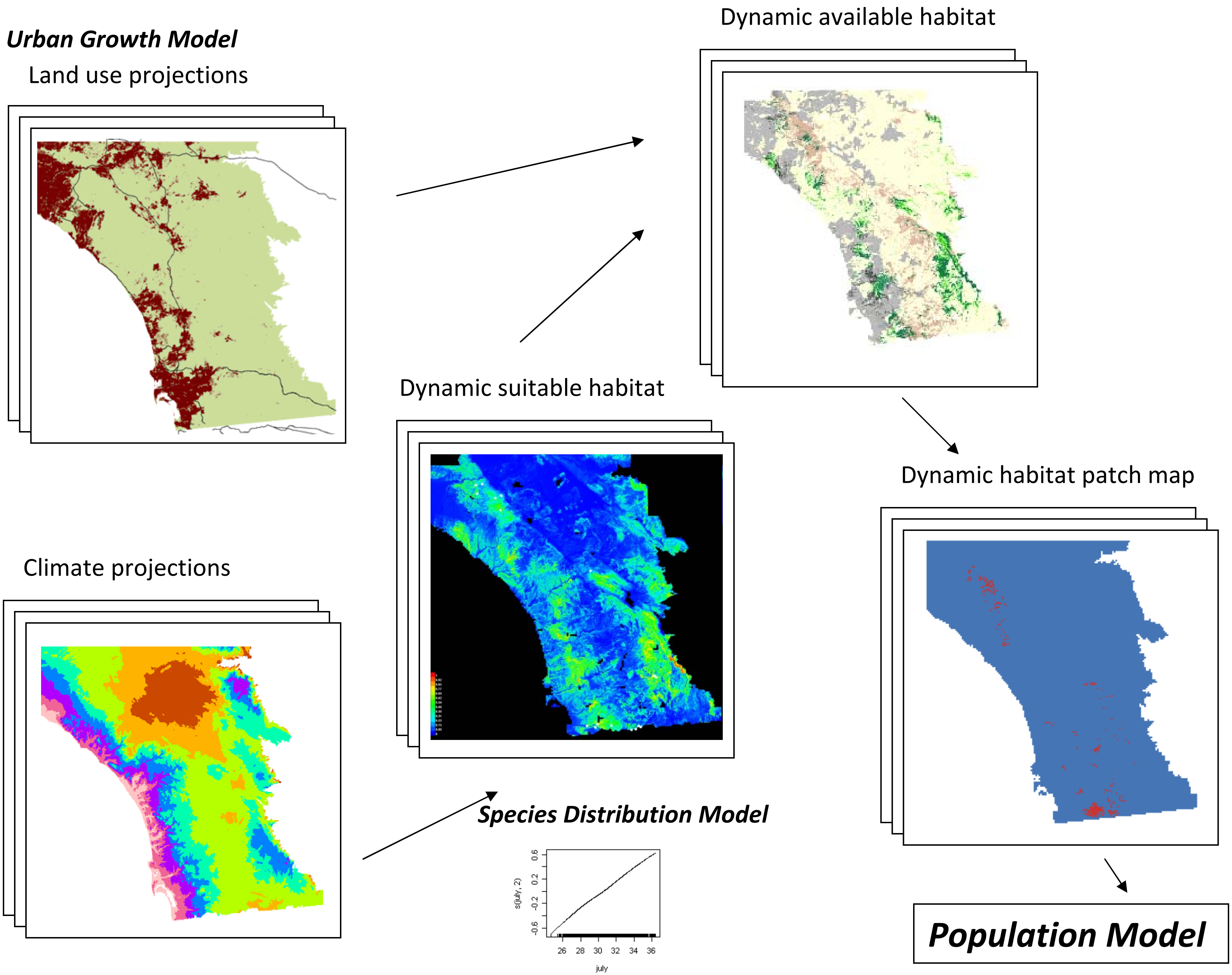
Evaluating Threats and Management Options

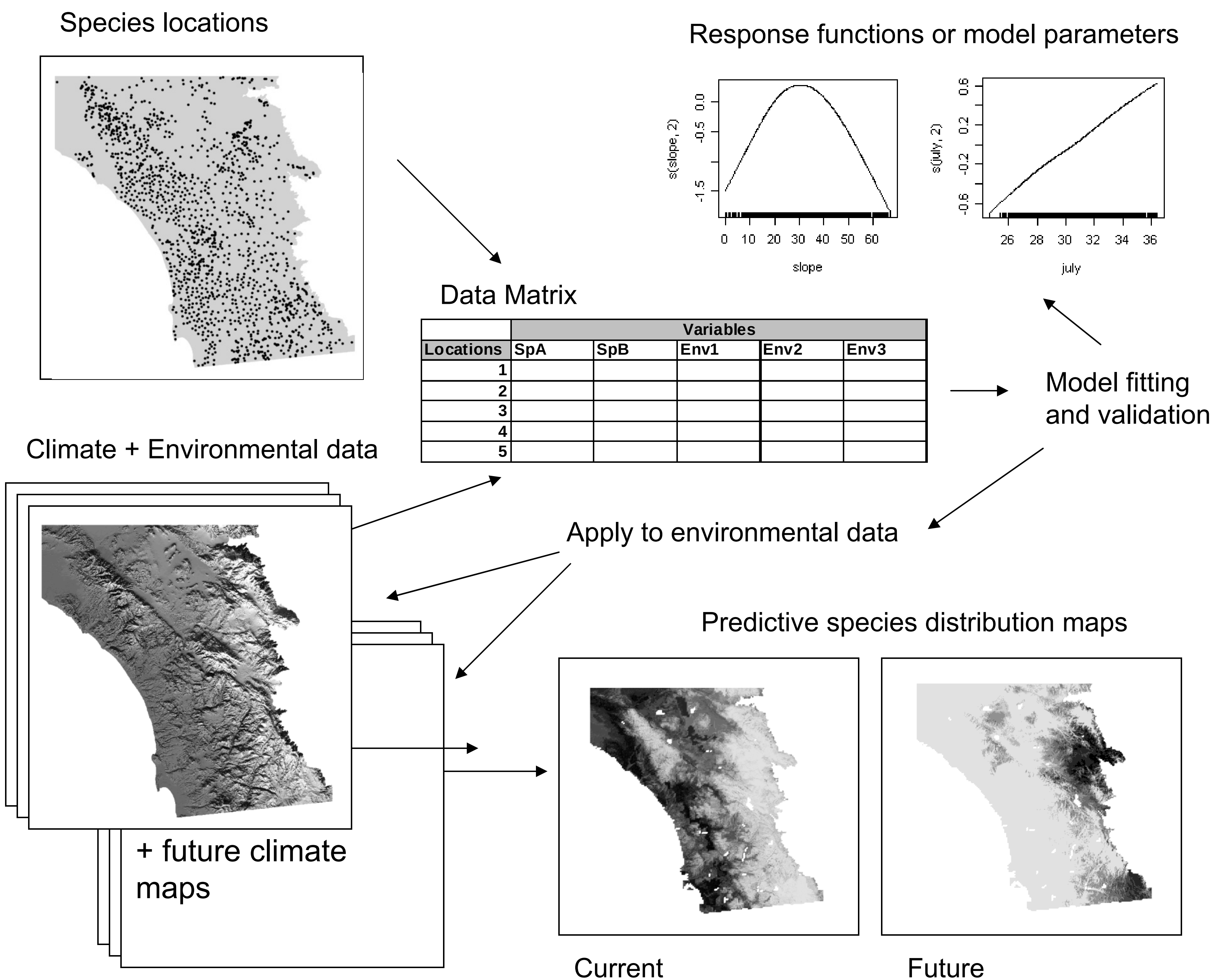
- Uncertainty of climate change & interacting threats
  - Climate projections, species models, species responses
- Need adaptation strategies, tools
- Management solely on species distribution models assumes:
  - Models successfully predict future habitat
  - Future habitat supports viable subpopulations
- Depends on species demography, population dynamics

Modeling Framework

- Stochastic population models & dynamic bioclimatic SDMs
- Relative impacts and alternate management options for rare plants in southern CA
  - Climate change
  - Altered fire regimes
  - Land use
- Functional types (Tecate Cypress, obligate seeder)
- Risks vs. benefits considering multiple threats and uncertainty

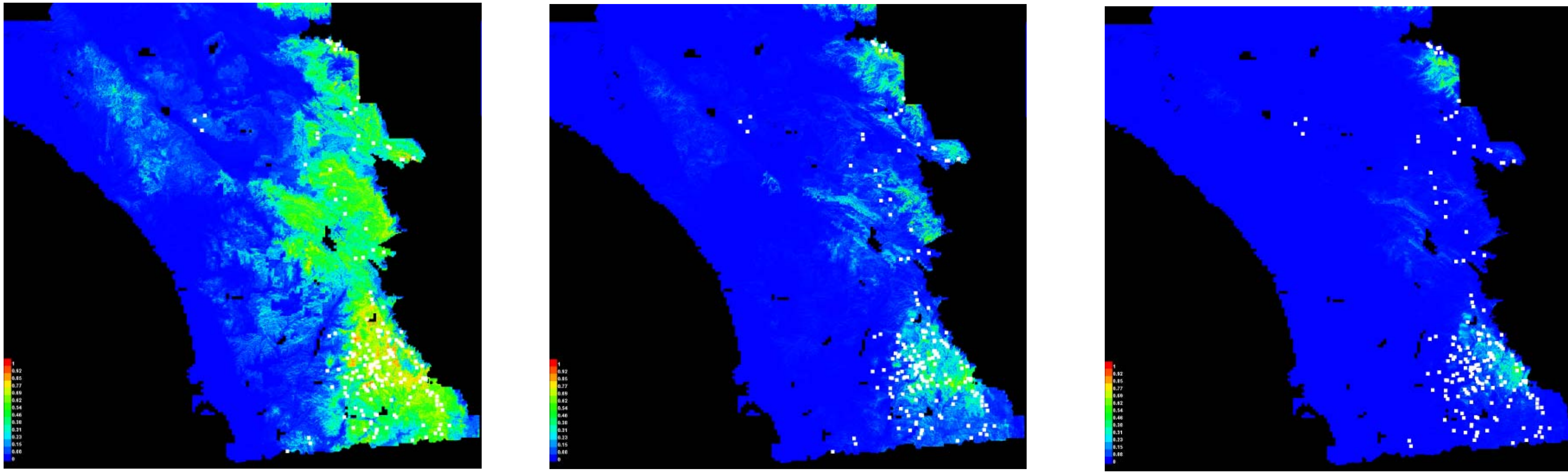



Urban Growth Model
Land use projections
Dynamic available habitat
Dynamic suitable habitat
Climate projections
Species Distribution Model
s(july, 2)
july
Dynamic habitat patch map
Population Model

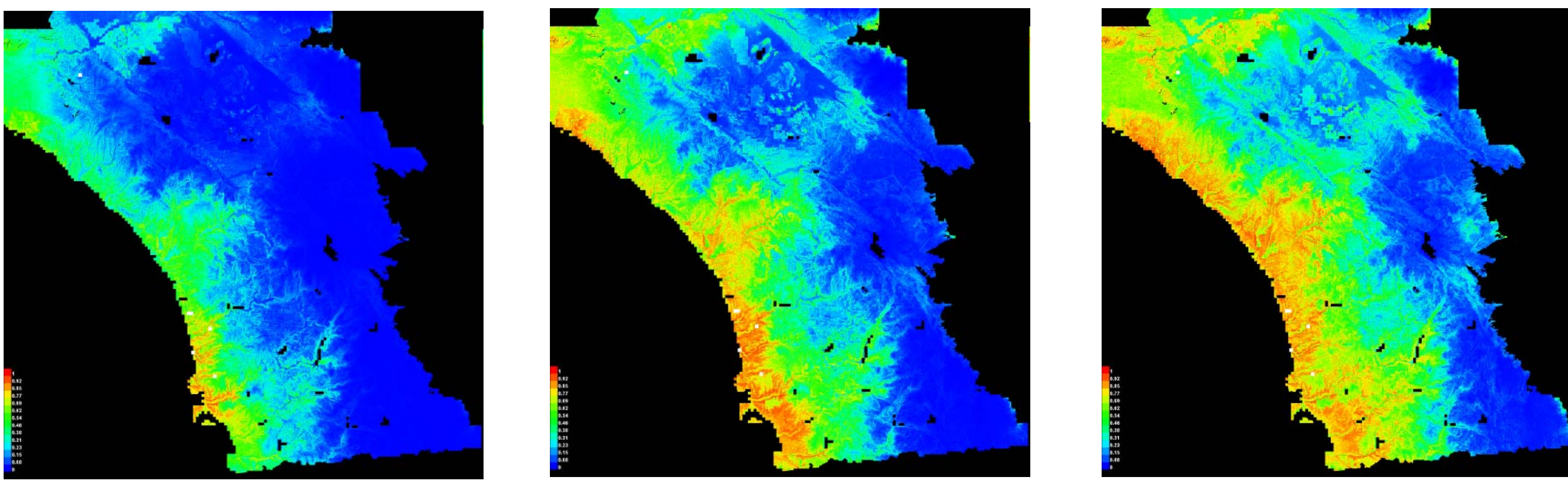


Species locations
Response functions or model parameters
s(slope, 2)
-1.5
-0.5
0.0
0
10
20
30
40
50
60
slope
s(july, 2)
-0.6
-0.2
0.2
0.6
26
28
30
32
34
36
july
Data Matrix
Variables
Locations
SpA
SpB
Env1
Env2
Env3
1
2
3
4
5
Model fitting
and validation
Climate + Environmental data
Apply to environmental data
Predictive species distribution maps
+ future climate
maps
Current
Future

Ceanothus greggii



Chorizanthe orcuttiana



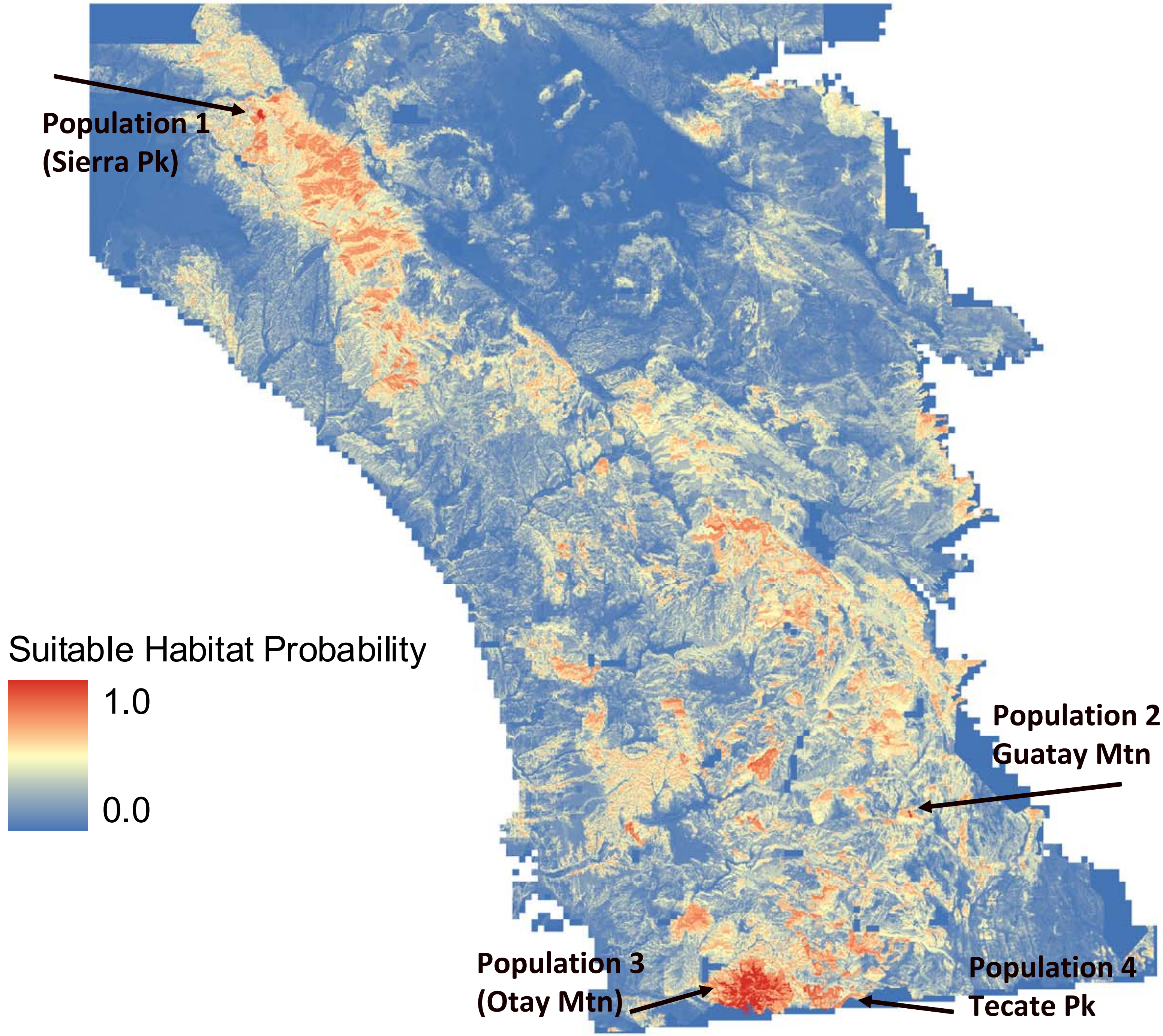
Current (2000) | Future PCM A2 | Future GFDL A2

Tecate cypress (*Cupressus forbesii*)

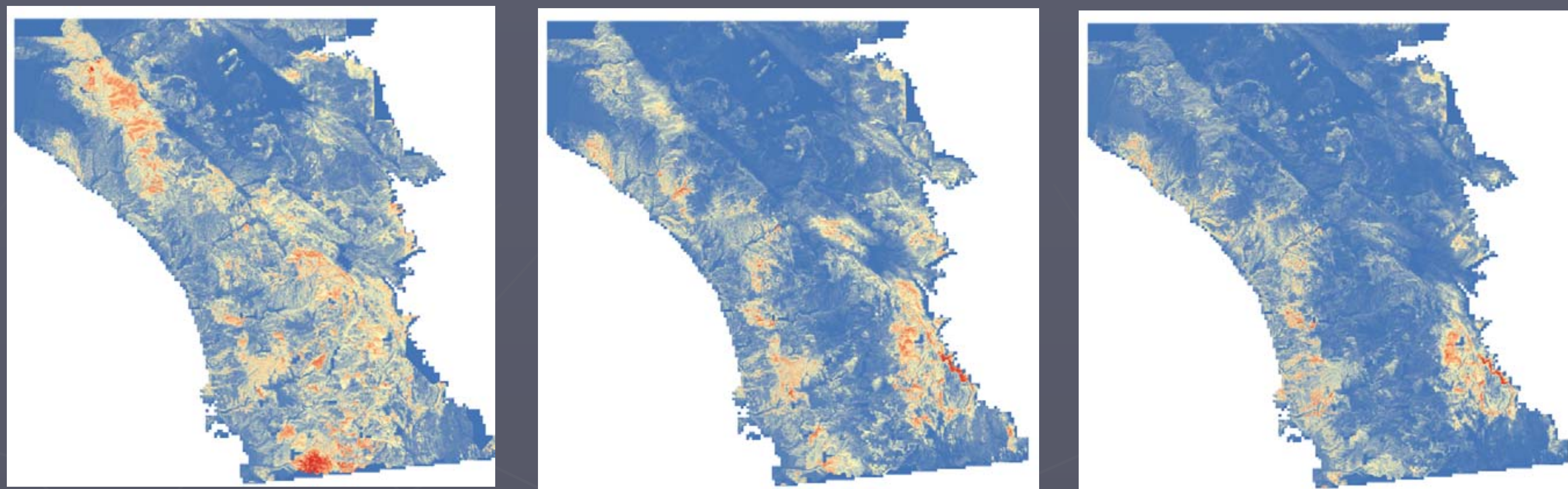
- Mediterranean ecosystem plant
- Rare, regional endemic
- Fire dependent
- Threatened by altered fire regime
  - Obligate seeder – time for seed bank
- and urbanization (affects fire regime)
- List 1B: Plants Rare, Threatened, or Endangered in California and Elsewhere
- "Assisted migration" (to future suitable habitat)

Modeling Experiments and Research Questions

- What are the impacts of climate change?
- How much assisted migration is necessary to maintain population persistence under climate change?
- How does survival of translocated plants influence population persistence?
- Does any of this depend on fire regime?


Population 1
(Sierra Pk)
Suitable Habitat Probability
1.0
0.0
Population 2
Guatay Mtn
Population 3
(Otay Mtn)
Population 4
Tecate Pk

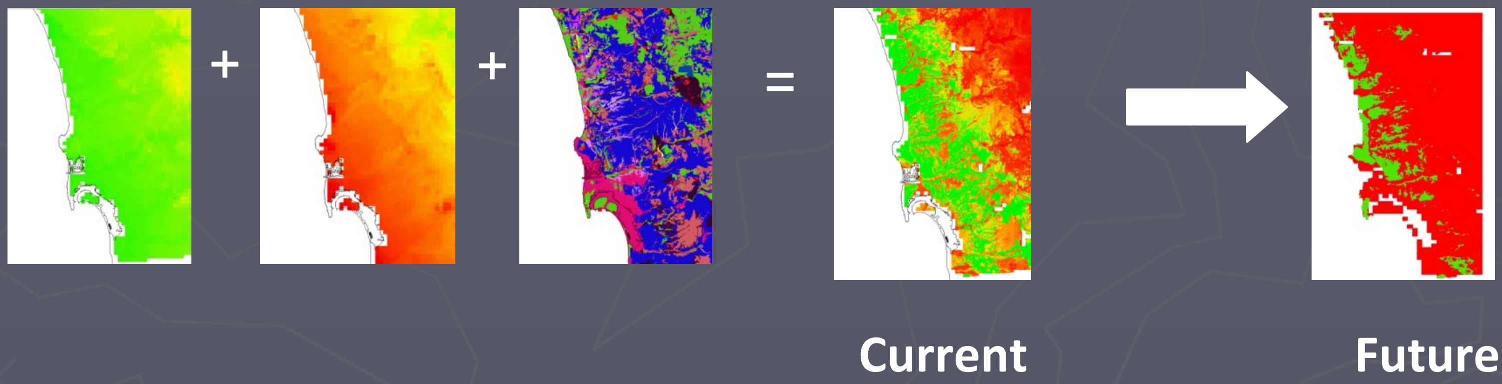
Current | 2100 PCM A2 | 2100 GFDL A2



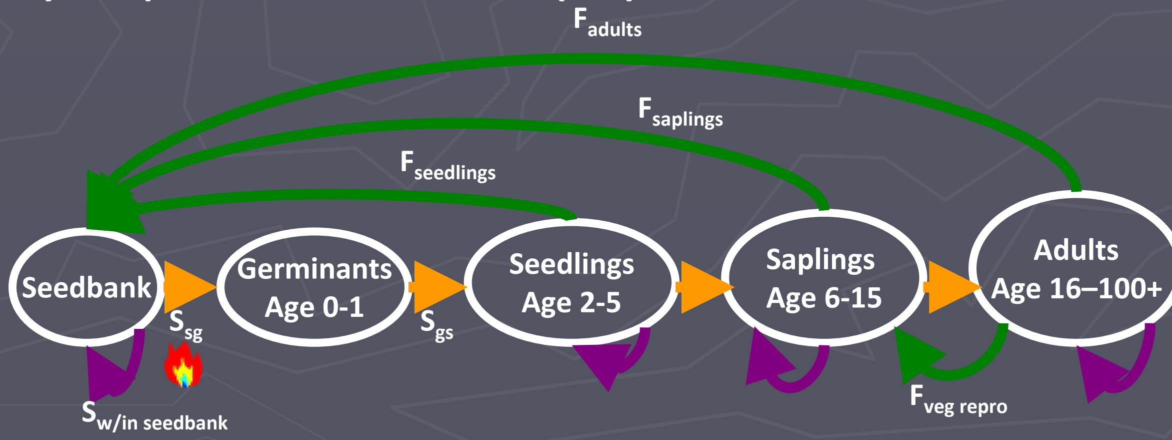
Continuous distribution probability thresholded Into habitat patches

Modeling Effects of Climate Change

- Habitat suitability models

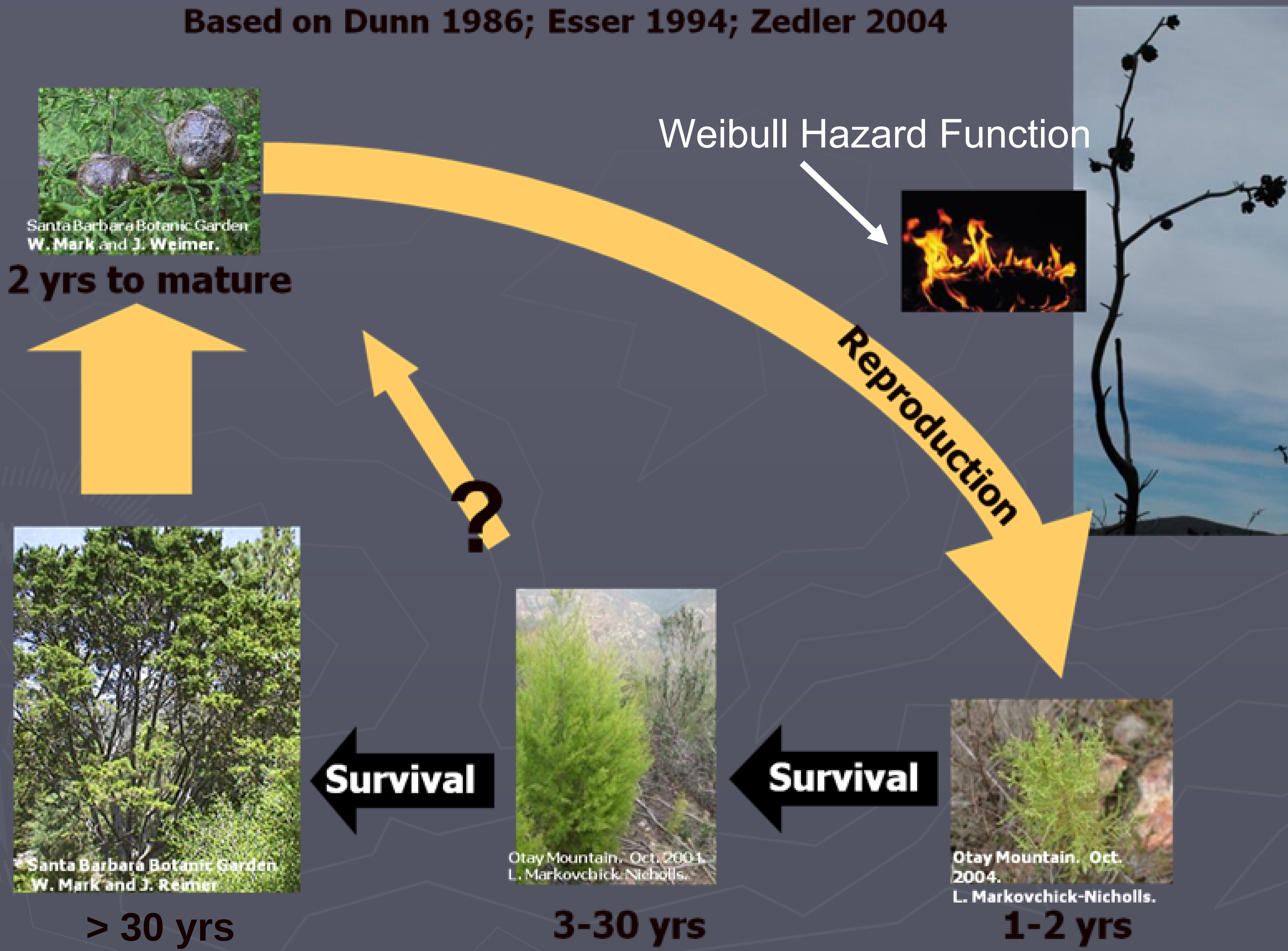


- Spatially explicit stochastic population models



Population model

Based on Dunn 1986; Esser 1994; Zedler 2004

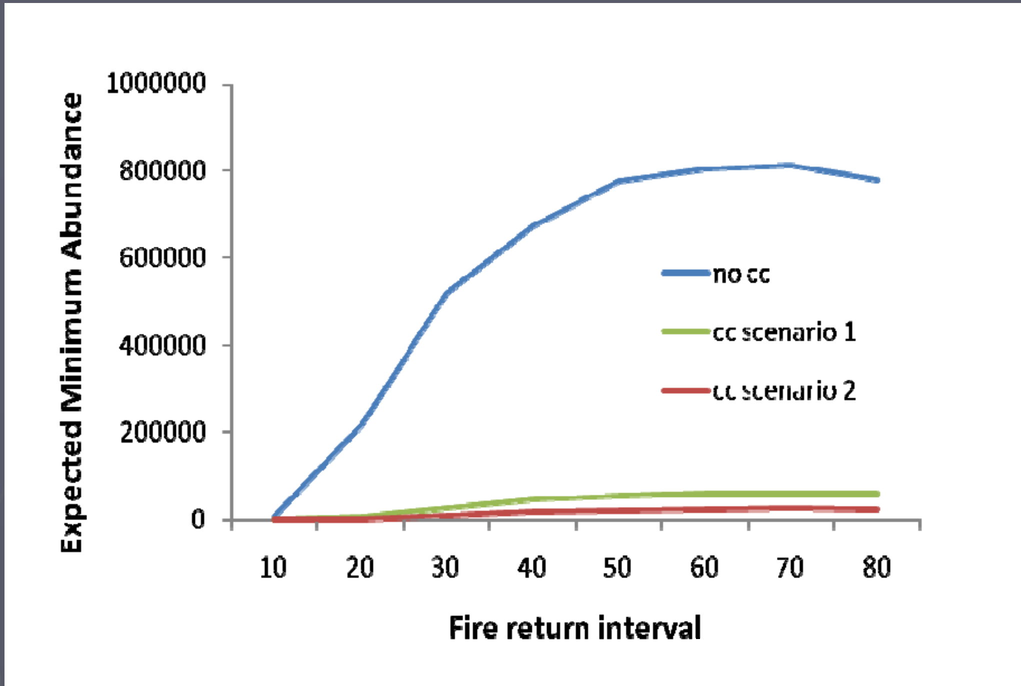


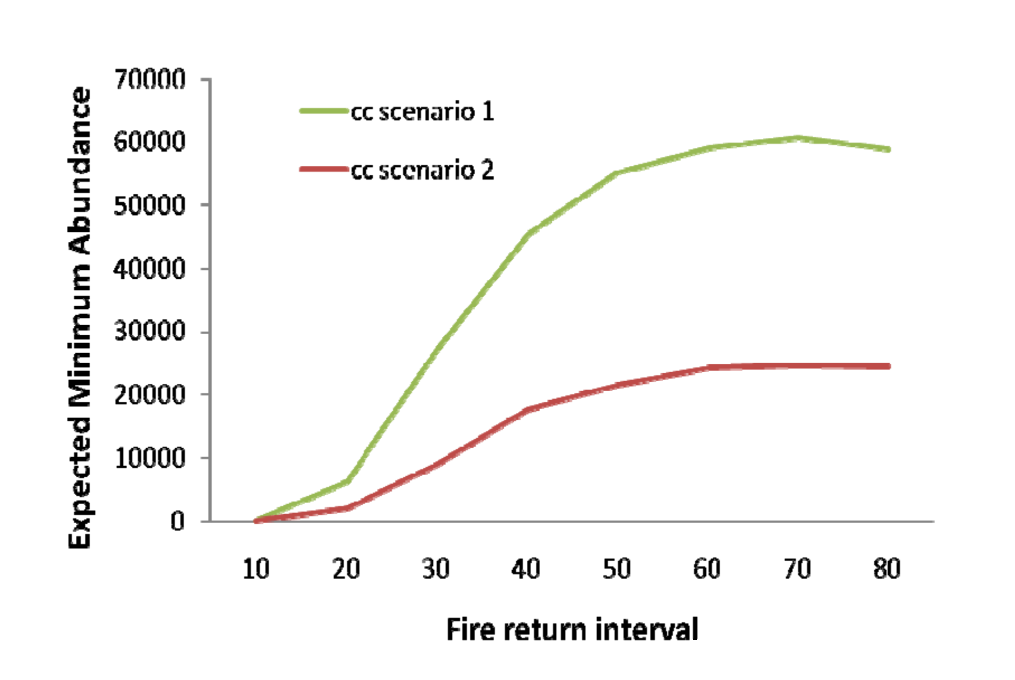
Translocation with Climate Change

- Otay population used as source population
- Translocation of seedlings after fire event
- Translocation limited to the first 40 yrs, after which Otay Peak's habitat suitability decreased

Translocation with Climate Change

- 3 target patches selected
  - had continued suitable habitat for both climate scenarios
  - patches were geographically close to source patch
- 10%, 20%, and 30% of seedlings were translocated across 1, 2, and 3 patches, respectively
- Tested different translocation success rates under 2 climate change scenarios





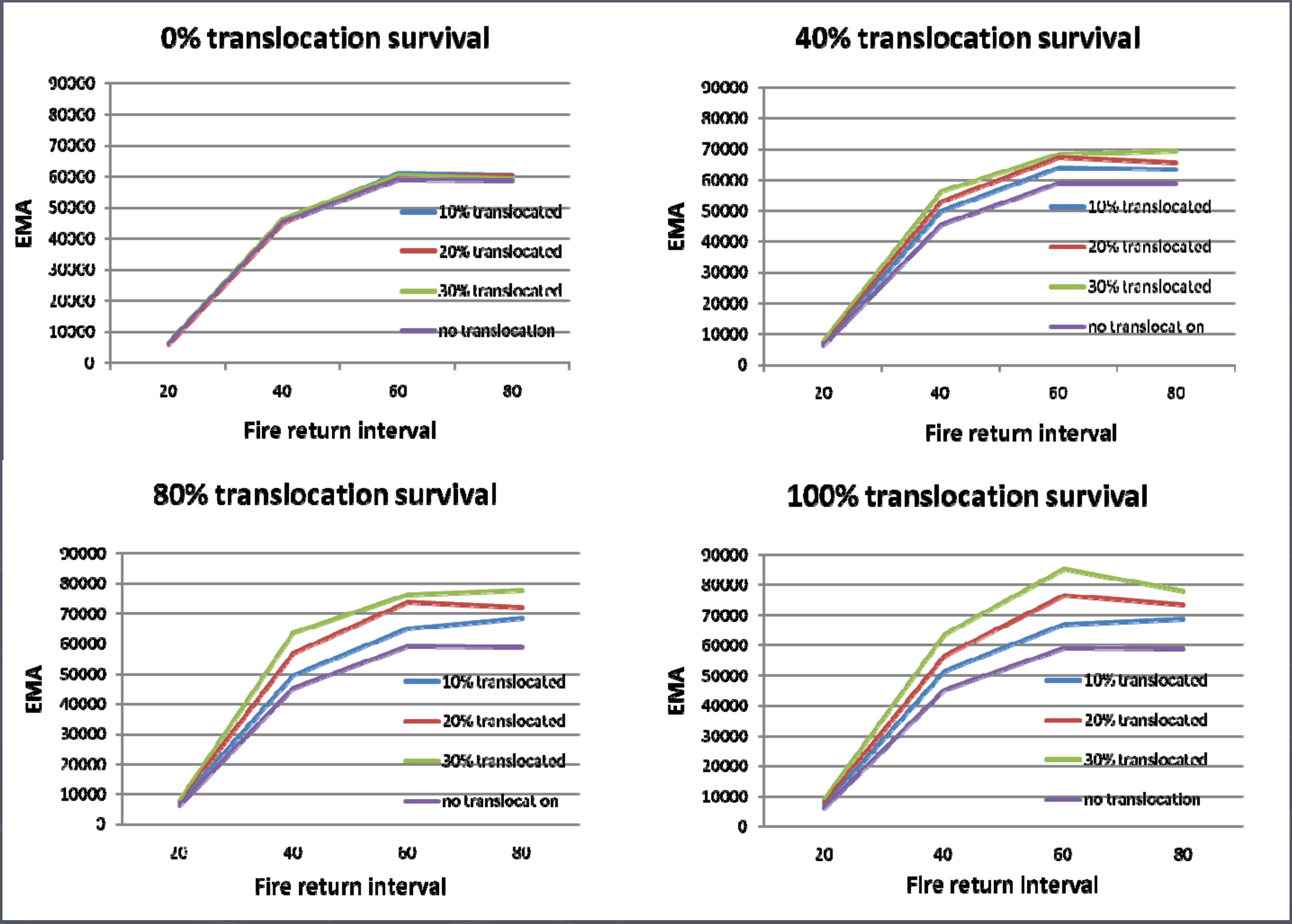
CC scenario 1 = PCM
CC scenario 2 = GFDL

Longer average fire return intervals better than shorter FRIs

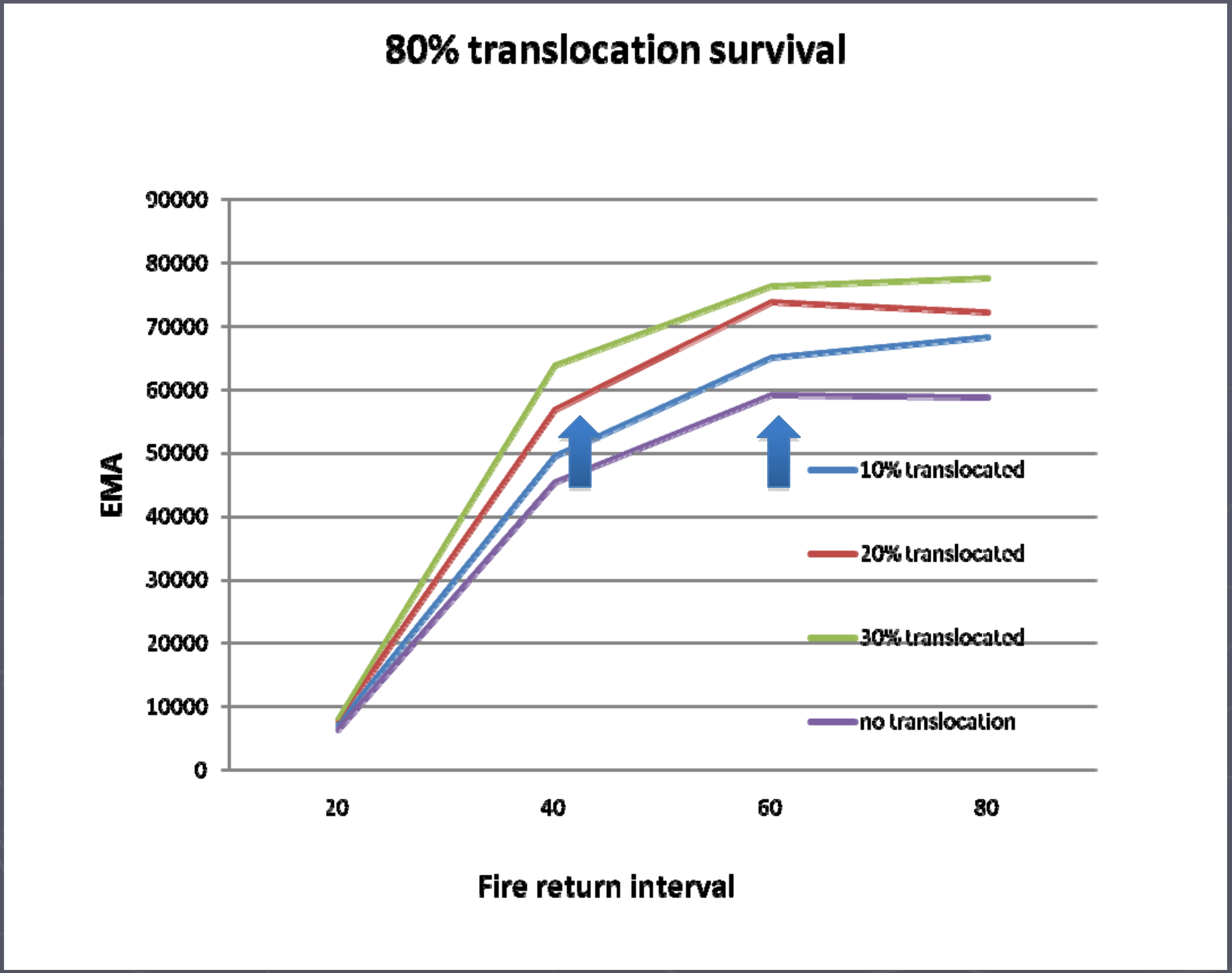
60 – 80 year average fire return intervals optimal

Pattern maintained with and without CC & across different CC scenarios

PCM


0% translocation survival
40% translocation survival
80% translocation survival
100% translocation survival
EMA
Fire return interval
20
40
60
80
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
10% translocated
20% translocated
30% translocated
no translocation

Translocation vs. Less Fire



Summary

- As previous studies have shown, short fire return interval is a big threat to persistence of long-lived obligate seeders
- Even at moderately high levels of translocation/survival, the benefits of reducing fire frequency are predicted to be greater than the benefits of translocation
- Modeling framework is a tool for comparing multiple threats in context of climate change, benefits of management actions, and trade-offs

Using Framework for Future Study

- Interacting, cumulative threats
  - Urban development
  - Feedbacks among fire and climate and urban
- Dispersal mitigating climate change for resprouters
- Alternate management options
  - Protected areas
  - Fire management
  - Habitat restoration
- Species:
  - *Quercus engelmannii*
  - *Ceanothus verrucosus, Ceanothus greggii,* Tecate cypress
  - *Chorizanthe orcuttiana, Acanthamintha ilicifolia*, Otay tarplant
  - *Eryngium aristulatum,* Cuyamaca larkspur

Acknowledgements

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- Dr. Mary Ann Hawke, San Diego Natural History Museum
- National Science Foundation
- Department of Energy

Extra slides

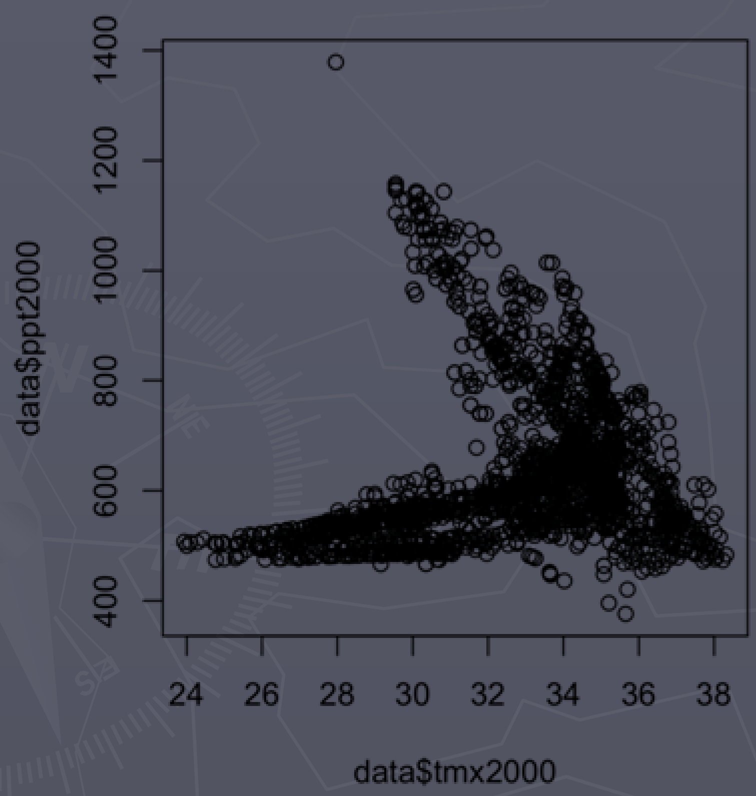
Variable	Resolution	Source
Mean annual minimum temperature (tmn)	1 km	PRISM
Mean annual maximum temperature (tmx)	1 km	PRISM
Mean annual precipitation (ppt)	1 km	PRISM
Mean summer solstice solar radiation (sumrad)	30 m	Derived from DEM (U.S. Geological Survey)
Mean winter solstice solar radiation (winrad)		Derived from the DEM
Slope gradient (slope)	30 m	Derived from the DEM
Topographic Moisture Index (tmi)	30 m	Derived from the DEM
Soil order (soiltype)	1:250,000	California State Soil Geographic Database STATSGO data base for California, U.S. Department of Agriculture Natural Resources Conservation Service (1)
Available Water Capacity (Awcl)	1:250,000	STATSGO
Soil Depth (depl)	1:250,000	STATSGO
Soil pH (phl)	1:250,000	STATSGO

Maxent model

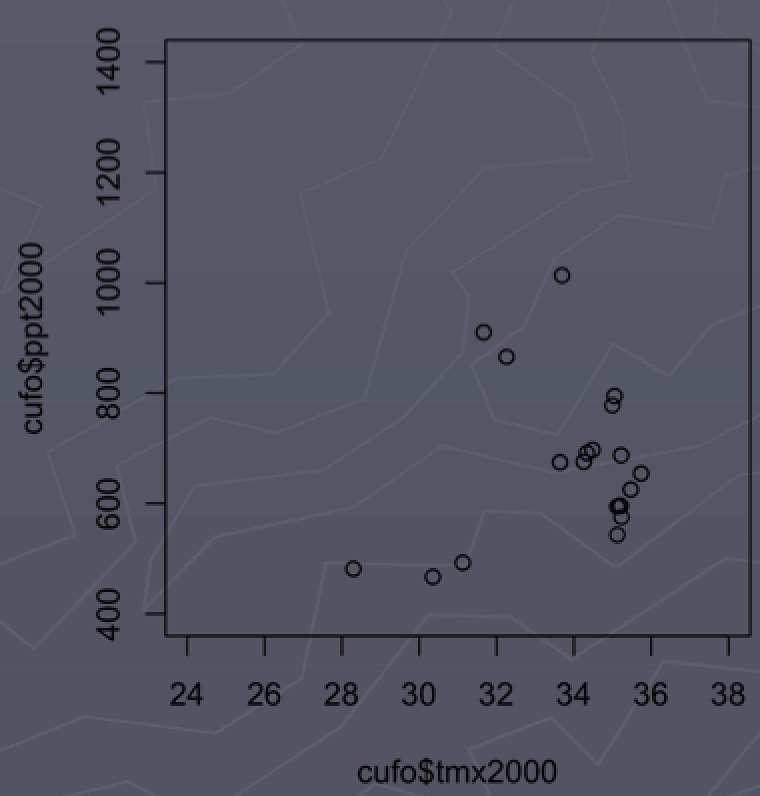
Variable	Percent contribution
slope	41.4
soilcode	21.3
winrad2	15.2
phl	8
awcl	6.9
tmx	**6.7**
ppt	0.2
depl	0.2
tmn	**0**
tmi	0
Sumrad2	0

T max vs. Precip

All vegetation plots



Tecate Cypress

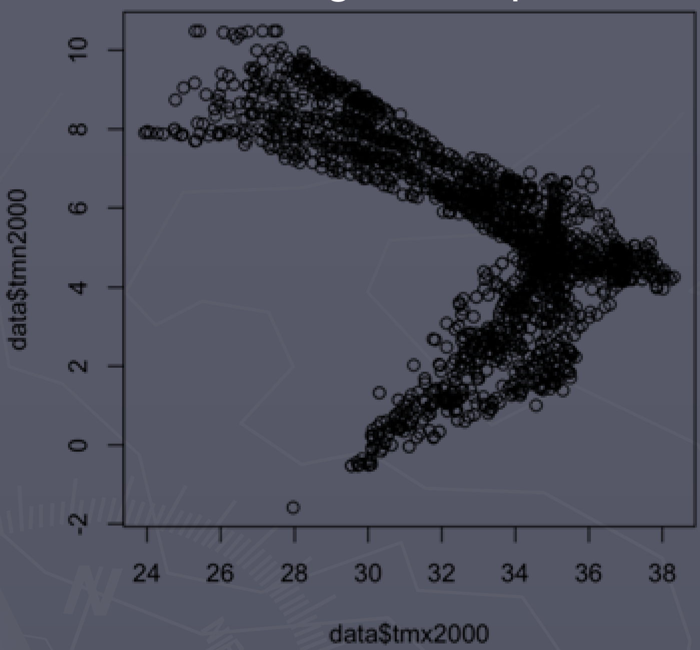


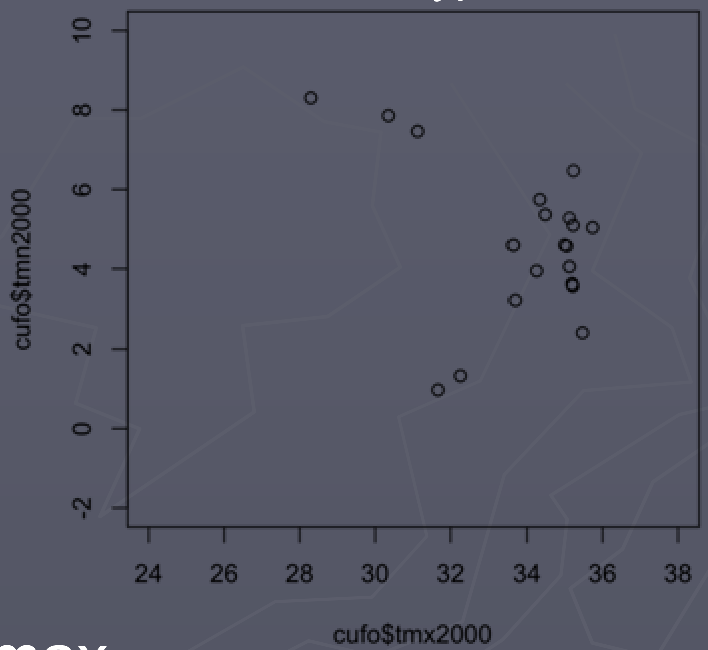
Average minimum temperature of coldest month vs. Average maximum temperature of warmest month

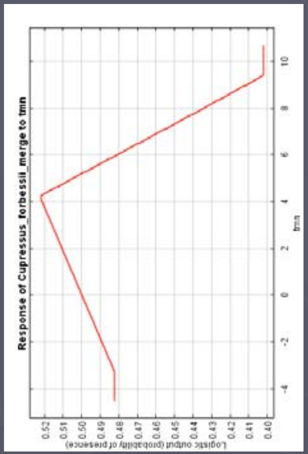
All vegetation plots

Tecate Cypress

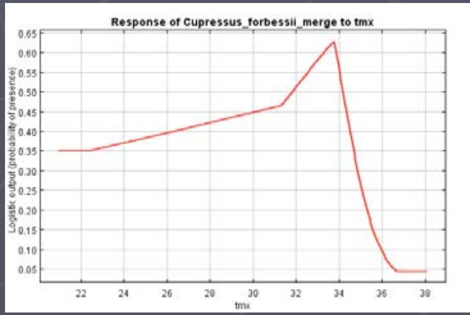
Tmin



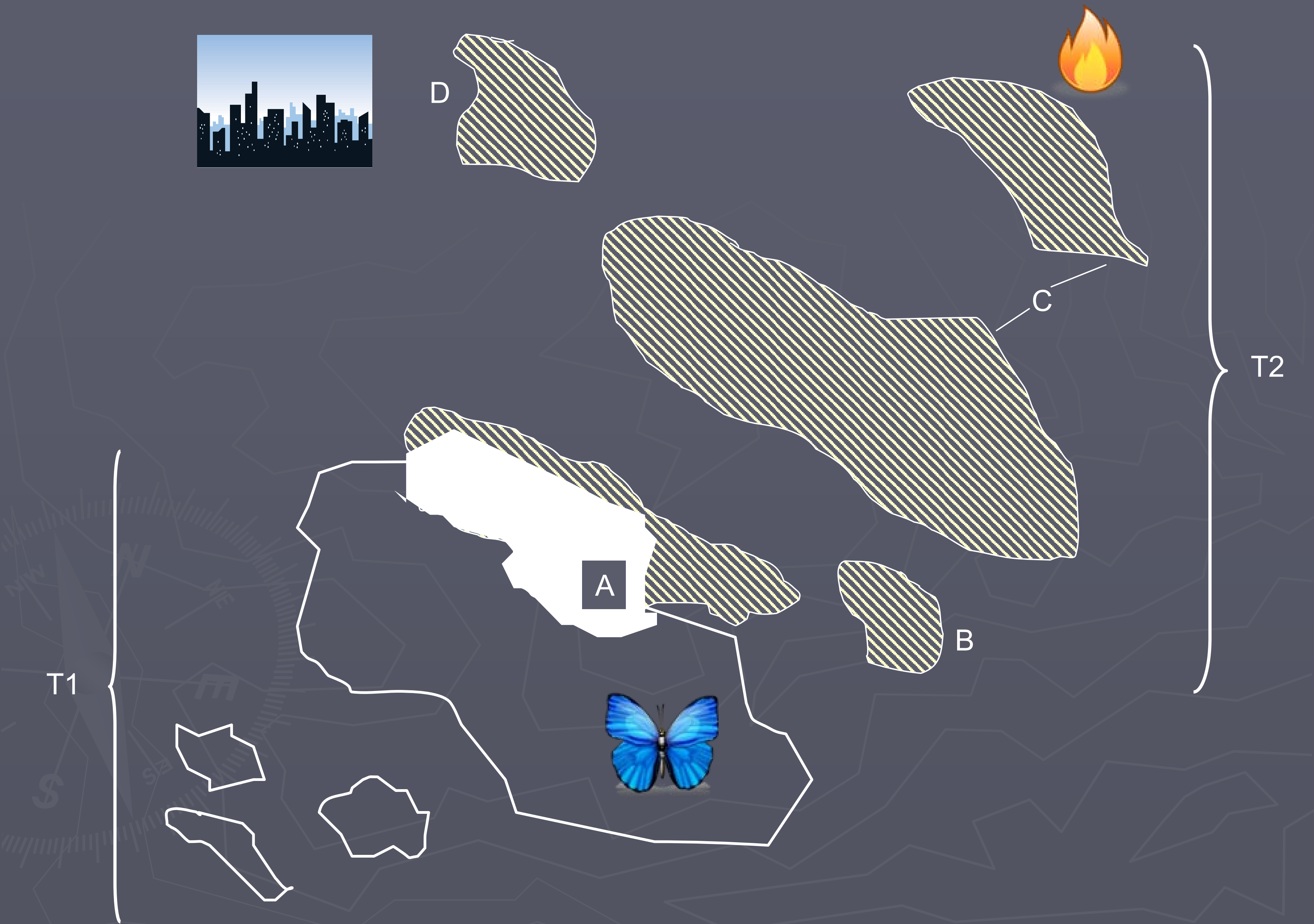




Tmax



Maxent
Response
curves



D
C
T2
A
B
T1

Extinction Risk & Climate Change

Traditional approach

Prediction of range shifts using bioclimatic envelopes. (Loarie et. al. 2008; Thomas et. al. 2004).

Limitations

Shifts and contractions of suitable climates do not easily translate into extinction risks

Doesn’t take into account demographic processes.

Recent approach

Link dynamic bioclimatic envelopes with stochastic population models
(Keith et. al. 2008; Anderson et al. 2009)

Tecate cypress

- Host plant for Thorne's hairstreak butterfly
- April 2010 USFWS deemed "ESA listing may be warranted" after 20 years of petitioning
- Threats:
  - Habitat loss and fragmentation
  - Frequent fires

Initial Abundances

- Four initially occupied patches based on published surveys
  - Sierra Pk 265k (1000/ha x 265 ha)
  - Otay Mtn 5.2m
  - Tecate Pk 932k
  - Guatay Mtn 33k

Population model

- Age-based matrix model – data from literature (various), field data & expert opinion (Zedler)
- Spatially explicit
- Carrying capacity based on size of plants
- Initial population size based on published density estimates
- Stochastic vital rates and variable fire events
- Linked to fire hazard functions
- Explicit response to fire
- 100 years, 1000 replications
- Results in terms of Expected Minimum Abundance (comparable to, but more inclusive than, extinction risk)

Fire model

Average fire return intervals 10, 20, …, 80 yrs

Unplanned fires:

Weibull function

$$\lambda(t) = \frac{ct^{c-1}}{b^c}$$

(c=1.42 for chaparral)

(Polakow et al. 1999; Moritz 2003)

Adaptation – Management Responses

- “Assisted migration” (to future suitable habitat) akin to translocation (to previously occupied habitat) in traditional conservation management

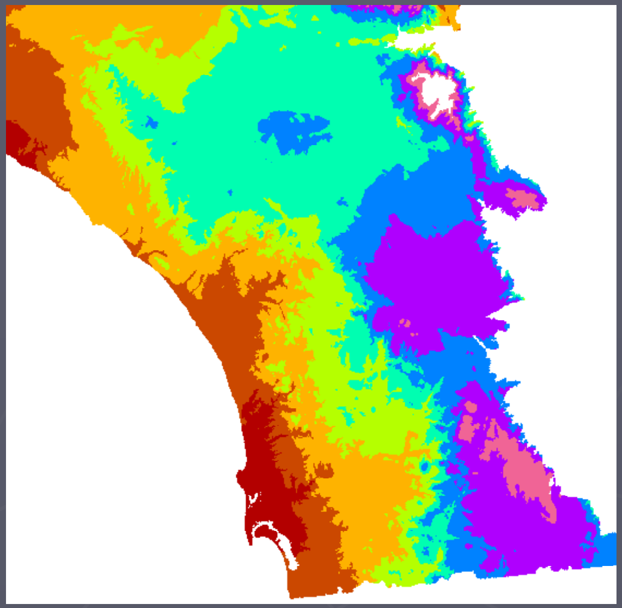
Management Responses (cont.)

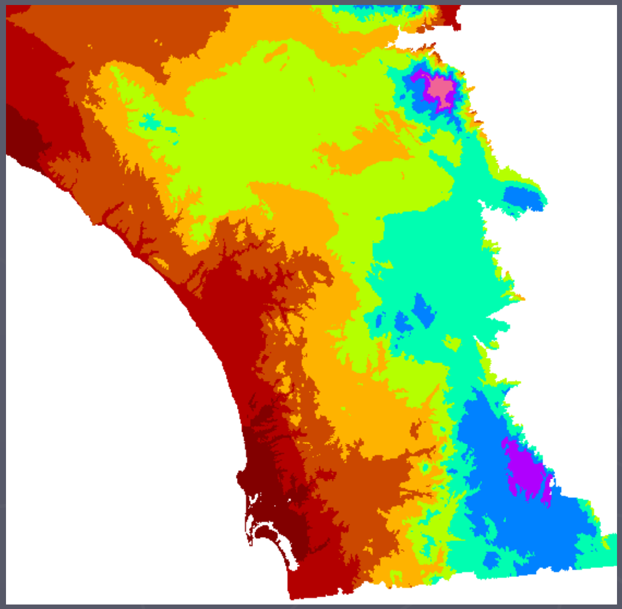
- Depends on species demography, population dynamics
- Evaluating likely success requires population projections and habitat dynamics (climate change)
- Dynamic bioclimatic species distribution models + stochastic population models

2000

2099

T min





T max